velocity was 17 miles per hour and in the other case it was 25 miles per hour. In all other cases it was not over 15 miles per hour.

The temperature was well below freezing during the precipitation of all the snows listed in Table 2.

Referring to Table 2 we find that the total amount recorded by the rain-gage can was 0.435 inches and that of the snow board to be 0.81 inches, or 1.86 times that recorded by the gage can. In a seasonal snowfall of 32 inches, which is the average for Grand Forks for a period of 31 years, the deficiency would be 27.5 inches or taking it over the 31 year period, the total deficiency would be 738.6 inches, if rain-gage can measurements have been strictly adhered to in the past measurements.

TWILIGHT PHENOMENA ON MONT BLANC

E. BAUER, A. DANJON and JEAN LANGEVIN

(Comptes Rendus, 178, no. 25, June 16. 1924, pp. 2115–17)

[Translated by B. M. Varney, Weather Bureau]

We have studied the twilight phenomena at the Vallot Observatory on Mont Blanc (4,347 meters) under excellent, perhaps even exceptional, atmospheric conditions. Observations first undertaken in August, 1922, have been carried out from the 9th to the 14th of August, 1923. The interesting thing about a study at this altitude is the extreme simplicity and the almost astronomic regularity of the phenomena. Certain phases described in the standard works [1] were, however, missing. It is likely that the complications observed at a low altitude are in large measure the result of conditions in the dusty lower layers of the atmosphere, which extend upward to 3,000 to 3,500 meters.

1. *Phenomena opposite the sun. The earth's shadow.*—At 180° from the sun, one sees the shadow of the earth on the atmosphere; this is the ascent of night (la montée de la nuit), a blue-black segment bordered with purple in its upper part.

TABLE 1.—*Altitude of the blue segment (a. m.)*

$h_\odot$ = true solar altitude	0°	−2°	−4°	−5°	−6°
Altitude of the segment	−2°	+2°	+7°30′	+15°	+26°

NOTE.—The dip of the horizon at Vallot observatory is −2°.

The boundary of the segment is lost before it reaches the zenith and when the solar altitude h. = −7°.

The intersection of the solar ray which is tangent to the earth with the straight line from the observer to the summit of the segment, describes an elliptical arc leaving the earth at a distance of 100 kilometers [from the observer] and reaching the zenith at an altitude of about 45 kilometers.

2. *Phenomena observed on the side toward the sun. We have seen no evidence of the first twilight arch (9° from the sun), nor of the purple lights.*—Photographic records confirm these negative conclusions. The only one of the phenomena observed with great regularity is the second twilight arch: at the horizon a reddish segment, above that a yellow segment, and finally a much larger segment of a greenish blue very pure in tone, its upper boundary rather sharply drawn, and above it the night. This varicolored segment appears to us to constitute a wholly unique thing, differing widely from that which one infers from the standard descriptions, which are mostly confused and contradictory.

It appears to be useless to make a distinction between the reflected light of twilight (the Dämmerungsschein of Pernter-Exner) [2] and the twilight arch properly so called.

TABLE 2.—*Altitudes of the twilight arch (p. m.)*

$h_\odot$	8°	10°	12°	14°	17°50′
Red/yellow boundary	−1°10′	−1°	−0°55′	−0°45′	----
Yellow/blue boundary	+0°40′	+0°30′	+0°10′	0°	----
Blue/night boundary	+10°	+7°30′	+4°35′	+2°20′	−2°

The boundary of the twilight arch (blue/night) passes the zenith at a solar altitude of −4° 40′. It is thus a phenomenon independent of the ascent of night, the edge of which attains the zenith only when the solar altitude is −7° or −8°. The arch disappears completely at h. = −17° 50′.

It seems to us impossible to explain the twilight arch on the basis of a reflection of the purple light as Pernter and Exner have done.[3] It appears more likely that it is due to diffusion of direct sunlight by the atmosphere included between the shadow cone of the earth and a certain limiting altitude z. But if we compute z, we obtain numbers which increase as the sun declines.

TABLE 3.—*Altitude of the twilight arch (p. m.)*

$-h_\odot$	4°35′	10°	14°	16°	17°
z (km.)	14	30	39	42	44

It is to be observed that the measurements of the twilight arch and of the ascent of night give the same altitude for the highest diffusion layers, about 45 kilometers.

We have observed 30 minutes after the setting of the twilight arch, a new luminous segment, very faint, fairly well defined but irregular, which disappeared little by little below the horizon.

This segment, which does not seem to be due to the zodiacal light, is perhaps a third twilight arch. Its summit is at about 9° altitude when $h_\odot = -21°$. The diffusion layer which would cause it would therefore reach 180 kilometers altitude and would be identical with the absorptive layer observed by us in 1922.[4]

3. *Photometric measurement of the brightness of the zenithal sky.*—The measurements were carried out according to the photometric method of Fabry,[5] slightly

[1] Pernter and Exner, Meteorologische Optik, 2d ed., 1922, p. 845 et seq.

[2] loc. cit., p. 856.

[3] loc. cit., p. 898.

[4] Comptes Rendus, 176, 1923, p. 761.

[5] The Director of the Bureau of Standards, Washington, D. C., has kindly contributed the following comment on the nature of the Fabry photometric method.

"While the reference to method of measurement is somewhat indefinite, we judge that it refers to a type of photometer described by H. Buisson and Charles Fabry in the Journal de Physique, page 25, 1920. A brief description of this instrument is also given in abstracts printed in the Transactions of the Illuminating Engineering Society, volume 16, page 92, 1921. This instrument is designed particularly for the measurement of very faint sources, and apparently it can be used for the direct comparison of the light from a small source with that for a luminous area. For example, it would make possible the direct comparison of the light from a star with that of a given area of the sky, and it would then be possible to express the brightness of a given region in terms of the intensity of a single star such as Vega. This would involve simply an estimate or a determination of the solid angle included in the field of view of the photometer, and evidently the authors have expressed this solid angle in a unit which they call a 'degree square.'"

modified. The absolute values of the brightness M, expressed in [star] magnitudes per degree square, have been determined with reference to Vega $0^m.14$ as unity.[6]

TABLE 4.—*Brightness of the zenithal sky*

$h_\odot$	$-7°$	$-9°$	$-11°$	$-13°$	$-15°$	$-16°$
M	$-3^m.0$	$-1^m.35$	$+0^m.25$	$+1^m.80$	$+3^m.10$	$+3^m.65$
$h_\odot$	$-17°$	$-18°$	$-20°$	$-25°$ to $-29°$		
M	$+4^m.00$	$+4^m.10$	$+4^m.20$	$+4^m.27$		

Beyond $h_\odot = -18°$, the brightness remains virtually constant, the brightness found agreeing with those of the nocturnal sky. Since they were obtained very close to the plane of the Milky Way, in the constellation Cygnus, they are doubtless a little too large.

It is clear that the end of twilight at the zenith coincides with the setting of the second twilight arch, at $h_\odot = -17° 50'$. Hence the two phenomena are related. The twilight arch diffuses the direct light of the sun a first time; this is then reflected once again by the atmosphere of the zenith.

In support of this explanation we may cite the parallelism, without any abscissal lag (décalage d'abscisse), between the curve found by us for the zenith and that which has been obtained by Fessenkopf for 70° zenith distance in the azimuth of the sun.

[6] Superior *m* as here used stands for star magnitudes, expressed decimally.

NOTES, ABSTRACTS, AND REVIEWS

George Titus Todd, 1866-1924

George T. Todd, meteorologist, died at Albany, N. Y., on November 12, 1924. His death was due to a sudden attack of acute dilation of the heart and occurred within 12 hours after he had delivered a lecture on the weather at the Mount Ida Memorial Presbyterian Church at Troy, N. Y.

Mr. Todd entered the Signal Corps on January 4, 1887, and after the usual preliminary course of instruction was assigned as a clerk at the central office at Washington, D. C., and afterwards as assistant at Detroit and Port Huron, Mich., and Memphis, Tenn. He was in charge of the station at Dodge City, Kans., from February, 1890, until November, 1902; at Wichita, Kans., from November, 1902, until May 3, 1905; and at Albany, N. Y., from May, 1905, until the time of his death.

Mr. Todd served the country continuously for 38 years with credit to himself and the Weather Bureau, and with great benefit to those for whom he especially labored. He was a very efficient member of our organization, faithful, conscientious, and courteous in all his undertakings and associations, and an honored and respected member of the communities in which he served. He was not only a Federal official; he was a citizen of the communities in which he lived. He devoted much of his time to them, and their interests were his interests.

In Albany Mr. Todd's skill and judgment in handling the complex flood problems in the spring, the heavy snows and cold waves of winter long ago made his name a household word throughout eastern New York, and his genius in these respects was the means of saving many millions of dollars to the business interests of that congested district.

Mr. Todd left a wife, a son, a daughter-in-law, and a grandson. He was a member of the Masonic fraternity and he was also a prominent member of the Rotary Club of Albany. Perhaps his most distinctive personal characteristics were his unfailing optimism and cheerfulness. These were never wanting, whether he was engaged in forecasting a flood, in cultivating roses, perhaps his best loved diversion, or in promoting the welfare of his fellow man. His associates in the Weather Bureau and the people of Albany and vicinity will hold his name in affectionate memory. (H. C. F.)

GRASSLAND AS A SOURCE OF RAINFALL[1]

551.578.1

F. E. CLEMENTS

In the endeavor to secure a definite correlation between grassland and rainfall, the various associations, such as true prairie, mixed prairie, etc., have been used as indicators of the amount of precipitation. It has been assumed that typical grassland develops only under summer rainfall, but this is incorrect, as the bunch-grass prairie of the Pacific coast corresponds to a winter rainfall, and the desert plains of the Southwest to a two-season or a summer-winter rainfall. In short, the amount of precipitation and evaporation rather than their calendar occurrence, seem to be the controlling factors.

The fact that a plant may transpire more water than a water body of equal surface evaporates, led to experiments to measure the transpiration of representative prairie communities. This was done by incasing sods in 3-foot cylinders without disturbing the roots and weighing these at the desired intervals in the true prarie, mixed prairie and short-grass plains, with annual mean rainfall, respectively, of 28, 23, and 17 inches. It was found that the transpiration in each community was more than equal to the precipitation occurring on it during a year. At Lincoln in the true prairie and Phillipsburg in the mixed prairie the transpiration was about 60 inches for the six-month growing season. This was approximately twice the mean rainfall and somewhat less than twice the evaporation from a free water surface. At Burlington in the short-grass plains, the transpiration for the four-month season was 40 inches or about twice the rainfall and somewhat less than the evaporation.

The cereal crops were found to transpire at about the same rate as the native grasses, while alfalfa lost somewhat more water. The water-loss from the native wheatgrass nearly equaled that from millet, while at Phillipsburg the loss from grama and from oats was the same, with bluestem transpiring nearly twice as much. The loss from alfalfa at Lincoln was about a third greater than that from bluestem. The results explain why ordinary settlement and cultivation have not increased rainfall, but suggest that afforestation over wide stretches would do so.

[1] Read at meeting of American Meteorological Society, Leland Stanford University, June 26, 1924.